REMARKS

Claims 1 and 115 – 229 are pending in the application. Claims 1, 129, 130, 140, 155, 166, 167, 193, 194, 209, 211 and 214 have been amended. Claims 154, 210, and 229 have been canceled. Claims 213, 216, and 220 have been objected to as being dependent upon a rejected base claim. Claims 1, 115 – 153, 155 – 209 and 211 – 228 remain in the application and are presented for reconsideration.

The Examiner rejected claims 115 – 118, 122, 131, 140 – 143, 147, 156, 167, 168, 172, 193, 194, and 198 under 35 USC § 102(e) as being anticipated by *Vafai, et al.* (U.S. Pat. No. 6,457,515). This rejection is respectfully traversed. The Examiner stated that *Vafai, et al.* discloses a layered microchannel heat sink comprising all of the applicants' claimed and disclosed limitations. Applicants disagree with this assertion. *Vafai, et al.* describes a two level heat exchanger with flow in opposite directions in the two layers, so as to reduce the typical inlet-to-outlet temperature rise in a simple heat exchanger design. The entire disclosure of *Vafai, et al.* is limited to a two-layered microchannel heat sink. The only embodiment disclosed in *Vafai, et al.* is that of a two stacked layers of microchannel heat sink structures, one atop the other, with coolant flowing in the opposite direction in each of the microchannel layers (col. 2, ll. 2 – 5, 41 – 51; col. 5, ll. 53 – 61; and col. 8, ll. 19 – 23). The channel arrangements depicted in *Vafai, et al.* are two layers of straight, parallel, uniform microchannels with flow in opposite directions in the two layers to help overcome temperature gradients from inlet to outlet. The analytical results

PAGE 31/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

presented in *Vafai, et al.* are based on two layers of rectangular channels. *Vafai, et al.* further teaches that pertinent geometrical parameters related to the thermal performance of a two-layered microchannel heat sink are the ratio of channel height to channel width, the ratio of fin width to the channel width, the size of the channels, and the stream-wise channel length of the heat-sink (col. 4, ll. 21 – 25).

In contrast, Applicants' claims are directed to non-uniform channel arrangements that address the temperature gradients that arise in the case of a simple, single layer, parallel, uniform microchannel design, or that arise from heat sources that are non-uniform. Figs. 3A, 3B, 4, 5, 18, 33, 34, 36, and 37 provide exemplary embodiments of non-uniform channel arrangements where the channel arrangements are tailored to address gradients that arise from the fluid distribution, as well as the gradients that arise from non-uniform heat sources. Furthermore, the present patent application describes a specific design methodology for optimization of the channel arrangement in view of any specific heat source geometry and heat distribution. In this regard, refer to Fig. 52, which provides a flow chart of the methodology in which permutations in the channel geometric designs are considered, a performance calculated, and iterations made towards a real optimal design. The result of such an iterative methodology is almost guaranteed to have a departure from straight, parallel, uniform channels, as taught by *Vafai, et al.*

With respect to claim 115, the second element of the claimed heat exchanger is "a microchannel disposed in the substrate for transfer of thermal energy to the fluid as the fluid is pumped through the heat exchanger, wherein the arrangement of the microchannel is selected to

PAGE 32/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

minimize the temperature differences across the heat-generating device." This element is not taught or suggested by *Vafai, et al.* *Vafai, et al.* teaches that temperature variations in the heat exchanger are reduced by the use of counter-flow in the two layers. Claim 115 is directed to an arrangement of the microchannel that is selected to minimize the temperature differences across the heat-generating device. The heat exchanger of claim 115 reduces temperature variations in the heat source, which is different from the teachings of *Vafai, et al.*, and certainly more important in a cooling system. Therefore, claim 115 is not anticipated by *Vafai, et al.* Claims 116 – 139 depend, either directly or indirectly from claim 115 and should be allowable for the same reasons that claim 115 is allowable over *Vafai, et al.*

Claim 140 is directed to a heat exchanger connected to a heat-generating device in a cooling system and has been amended to recite the limitation of "a high flow rate electroosmotic pump integrated into the substrate for pumping fluid through the heat exchanger". There is no teaching in *Vafai, et al.* of an electroosmotic pump integrated into the substrate; therefore, claim 140, as amended, is not anticipated by *Vafai, et al.* Claims 141 – 153 and 155 – 163 depend, either directly or indirectly from independent claim 140 and therefore should be allowable as well.

Claim 167 is directed to a cooling system for a heat-emitting device and recites as part of the substrate element: "the arrangement of the microchannel is selected to minimize the temperature differences across the heat emitting device." As discussed in the arguments above regarding claim 115, *Vafai, et al.* teaches that temperature variations in the heat exchanger are

PAGE 33/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

reduced by the use of the counter-flow in the two layers. Claim 167, however, reduces the temperature variations in the heat source, i.e., the heat-emitting device. Therefore, claim 167 is not anticipated by *Vafai, et al.* Furthermore, claim 167 has been amended to recite "a high flow rate fluid pump for creating the flow of the fluid". There is no teaching in *Vafai, et al.* of a high flow rate fluid pump, or for that matter, of any pump. Claims 168 – 192 depend, either directly or indirectly, from independent claim 167 and therefore should be allowable for the same reasons that claim 167 is allowable.

Claim 193 is directed to a cooling system for a heat-emitting device and has been amended to recite the limitation of "a high flow rate fluid pump for creating the flow of the fluid." As discussed above in conjunction with Applicants' arguments in differentiating claim 167 from *Vafai, et al.*, there is no teaching in *Vafai, et al.* of a high flow rate fluid pump. Therefore, claim 193 is not anticipated by *Vafai, et al.* Claim 124 – 208 depend, either directly or indirectly, from independent claim 193 and are allowable for at least the same reasons that claim 193 is allowable.

The Examiner rejected claims 1, 119 – 121, 123 – 130, 132 – 139, 145 – 146, 148 – 155, 157 – 166, 169 – 175, 184 – 192, 195 – 200, 204 – 212, 214 – 215, 217 – 218, 225 and 229 under 35 USC § 103(a) as being unpatentable over *Vafai, et al.* in view of *Arana, et al.* (U.S. Pat. Pub. 2003/0027022). This rejection is respectfully traversed.

The Examiner stated that *Vafai, et al.* discloses all of the claim limitations, except for the use of an electroosmotic pump; the multi-layer substrate being fabricated from a plurality of

PAGE 34/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

materials bonded together, a silver-filled epoxy or solder thermal interface material, a plurality of integrated circuits, and the substrate is disposed between the integrated circuits; the heat device being made from silicon, and the substrate from a metal; the micro-layers are made from metal and/or glass; and the use of temperature sensors, flow sensors, and feedback controls within the microchannels. The Examiner further stated that *Arana, et al.* teaches the use of a thermally efficient microchannel device having a heat exchanger for transferring heat in conjunction with an electroosmotic pump; the multi-layered substrate being fabricated from a plurality of materials bonded together, and the use of temperature sensors, flow sensors and feedback controls within the microchannel.

The Examiner concluded that give the teachings of *Arana, et al.* it would have been obvious to one of ordinary skill in the art at the time of the invention to modify the layered microchannel heat sink of *Vafai, et al.* with the use of an electroosmotic pump; the multi-layered substrate being fabricated from a plurality of materials bonded together; a silver-filled epoxy or solder thermal interface material; a plurality of integrated circuits, and the substrate is disposed between the integrated circuit; the heat device being made from silicon and the substrate from metal; the micro layers are made from metal and/or silicon and glass; and the use of temperature sensors, flow sensors, and feedback controls within the microchannel. The Examiner indicated that the motivation for making this combination of references would be to provide an improved and more efficient microchannel cooling device.

PAGE 35/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

Arana, et al. teaches a micro-machined device, including a fluid conducting tube having a thermally insulated inlet portion that carries fluid to an intermediate portion of the fluid conducting tube located in a thermally conductive region. The fluid conducting tube also has a thermally insulating outer portion that carries fluid away from the intermediate portion of the fluid conducting tube. Thermally conductive structures contact both the inlet portion and the outlet portion. The direction of fluid flow and the direction of conductive fluid flow are controlled separately. Direction of fluid flow is in the direction of the tube and conductive heat flow is at least partially through the thermal conductive structures (page 5, para. 56).

Arana, et al. further teaches that various sensors may be integrated into the micro-machined device, including temperature sensors, thermal conductance sensors, flow sensors, chemical sensors and others. Actuators may also be integrated into the micro-machined device such as resistive heater electrodes for electrophoresis or electroosmotic flow, etc. (page 5, para. 55).

Claim 1 has been amended to recite that the electroosmotic pump is a high flow rate electroosmotic pump clearly distinguishing this unique electroosmotic pump from all electroosmotic pumps known in the prior art. Support for high flow rate electroosmotic pumps can be found at page 5, lines 13 – 20; page 12, lines 7 – 11; page 28, lines 1 – 12; and page 33, lines 24 – 26. The teachings of *Vafai, et al.* and *Arana, et al.*, either taken alone or in combination, fail to teach a cooling system for a heat emitting device that includes a high flow rate electroosmotic pump for creating the flow of fluid through a substrate having at least a

PAGE 36/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

portion of the microchannel disposed therein. Generating flow in a microchannel by a combination of a fluid-filled tube and electrodes as taught by *Arana, et al.* is similar to typical electrokinetic systems such as are found in capillary electrophoresis systems. In such systems, large voltages are applied to generate low flow rates. This type of electrokinetic pump, although not explicitly disclosed in *Arana, et al.*, would not be useful in an electronics cooling system in which applied voltages are small and large flow rates are generated. Therefore, claim 1 is allowable over the combination of *Vafai, et al.* and *Arana, et al.*

Claims 119 – 221, 123 – 130 and 132 – 139 depend, either directly or indirectly, from claim 115. As discussed previously, claim 115 is not anticipated by *Vafai, et al.*, which discloses a two level heat exchanger wherein the channel arrangements in each of the two layers are restricted to sets of straight, parallel, uniform microchannels that flow in opposite directions in the two layers to help overcome temperature gradients from inlet to outlet. Likewise, *Arana, et al.* teaches embodiments of microchannels that are limited to uniform, parallel, geometric designs. There are no such limitations in the microchannels of the present invention. Furthermore, neither *Vafai, et al.* nor *Arana, et al.* teaches a channel arrangement selected to minimize the temperature variations in the heat source. Since claim 115 is allowable over the combination of *Vafai, et al.* and *Arana, et al.*, claims 119 – 121, 123 – 130, and 132 – 139 are allowable for at least the same reasons that claim 115 is allowable.

Claims 145 – 146, 148 – 155 and 157 – 163 depend, either directly or indirectly, from claim 140. As discussed above, claim 140 has been amended to recite the limitation of "a high

PAGE 37/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

flow rate electroosmotic pump integrated into the substrate for pumping fluid through the heat exchanger." Neither *Vafai, et al.* nor *Arana, et al.* teaches a high flow rate electroosmotic pump that is integrated into the substrate in which a microchannel is disposed. Therefore, claim 140 is not anticipated by *Vafai, et al.* and is patentable over the combination of *Vafai, et.al.* and *Arana, et al.* The limitation added to claim 140 previously appeared in dependent claim 154. Claim 154 has been canceled in this response. However, dependent claims 146, 148 – 153, 155 and 157 – 163, are allowable over the combination of *Vafai, et al.* and *Arana, et al.* for at least the same reasons that claim 140 is allowable over this combination.

Claim 164 recites the same limitation recited in claim 115 that the arrangement of the microchannel is selected to minimize the temperature differences across the heat-generating device. Neither *Vafai, et al.* nor *Arana, et al.* discloses an arrangement of a microchannel to minimize temperature differences across the heat source. Therefore, claim 164 is allowable over the combination of *Vafai, et al.* and *Arana, et al.* Claim 165 depends from claim 164 and is allowable for at least the same reasons given for the allowability of claim 164.

Claim 166 is directed to a heat exchanger for the transfer of heat from a heat-generating device in a cooling system. The claim has been amended to recite that fluid is pumped through the heat exchanger "by a high flow rate fluid pump." Neither *Vafai, et al.* nor *Arana, et al.* teaches a heat exchanger for a cooling system in which fluid is pumped at a high flow rate through the heat exchanger. Therefore, claim 166 is allowable over the combination of *Vafai, et al.* and *Arana, et al.*

Claims 169 – 175 and 184 – 192 depend, either directly or indirectly, from independent claim 167. Independent claim 167 is directed to a cooling system for a heat-emitting device and, as amended, recites the limitation of "a high flow rate fluid pump for creating the flow of fluid." Therefore, claim 167 is not anticipated by *Vafai, et al.* as discussed above and is allowable over the combination of *Vafai, et al.* and *Arana, et al.* Therefore, claims 169 – 175 and 184 – 192 are allowable for the same reasons that claim 167 is allowable over this combination of references.

Claims 195 – 200 and 204 – 208 depend, either directly or indirectly, from independent claim 193. Claim 193, as amended, recites the limitation of "a high flow rate fluid pump for creating the flow of fluid." Claim 193 is clearly not anticipated by *Vafai, et al.* as discussed above. Furthermore, claim 193 is allowable over the combination of *Vafai, et al.* and *Arana, et al.*, neither of which teaches a high flow rate fluid pump. Therefore, claims 195 – 200 and 204 – 208 are allowable over this combination of references for at least the same reasons.

Independent claim 209 is directed to a thermal transfer apparatus connected to a semiconductor heat emitting device and has been amended to recite the limitation of claim 210 "wherein the arrangement of the microchannels is selected to minimize the temperature difference across the heat emitting device." For reasons previously given, neither *Vafai, et al.* nor *Arana, et al.* discloses an arrangement of microchannels to minimize the temperature differences across the heat source. Therefore, claim 209 is allowable over the combination of *Vafai, et al.* and *Arana, et al.* Claim 210 has been cancelled by this response. Claims 211 – 212, 214 – 215, 217 – 218 and 225 depend, either directly or indirectly from independent claim 209.

PAGE 39/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

Therefore, these claims are allowable for at least the same reasons that claim 209 is allowable.

Claim 229 recites the same limitation as claim 210, which has been added to independent claim 209; therefore claim 229 is also canceled by this response.

Claim 176 – 183, 201 – 203, 221 – 224, 226 and 227 have been rejected under 35 USC § 103(a) as being unpatentable over *Vafai, et al.* in view of *Arana, et al.* and further in view of *Burdon, et al.* (U.S. Pat. No. 6,572,830). This rejection is respectfully traversed.

The Examiner stated that the invention of *Vafai, et al.* as modified by *Arana, et al.*, discloses all of the claim limitations except for the use of a plurality of vertical electrical connections; vertical and horizontal fluid channels; and an opening through which another interaction is capable of impinging upon the heat emitting device. The Examiner relies upon *Burdon, et al.* for a teaching of an integrated, multi-layered micro-fluidic cooling device, comprising the use of a plurality of vertical, electrical connections; vertical and horizontal fluid channels, and an opening through which another interaction is capable of impinging upon the heat emitting device referring to the abstract of *Burdon, et al.* The Examiner concluded that given the teachings of *Burdon, et al.*, it would have been obvious to one of ordinary skill in the art at the time of the invention to further modify the layered microchannel heat sink of *Vafai, et al.* with the use of a plurality of vertical, electrical connections; vertical and horizontal fluid channels; and an opening through which another interaction is capable of impinging upon the emitting device. The Examiner stated that the motivation for doing so would be to improve the

PAGE 40/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28

cooling performance by providing an alternative arrangement of fluid channels and providing electric connections for other circuits.

Claims 176 – 183 depend, either directly or indirectly, from independent claim 167. Claim 167, as discussed previously, is directed to a cooling system for a heat-emitting device having a high flow rate fluid pump for creating the flow of fluid. None of the applied references teaches a high flow rate fluid pump for creating the flow of fluid. Therefore, claims 176 – 183 are allowable for at least the same reasons that claim 167 is allowable.

Claims 201 – 203 depend, either directly or indirectly, from independent claim 193. Claim 193, as discussed above, has been amended to recite a high flow rate fluid pump for creating the flow of fluid. None of the applied references teaches a high flow rate fluid pump. Therefore, claims 201 – 203 are allowable for at least the same reasons that claim 193 is allowable.

Claims 221 – 224 and 226 – 227 depend, either directly or indirectly, from independent claim 209. Claim 209, as discussed above, has been amended to recite the limitation previously found in canceled claim 210 that "the arrangement of the microchannels is selected to minimize the temperature differences across the heat emitting device". Therefore, claims 221 – 224 and 226 – 227 are allowable over the combination of *Vafai, et al. Arana, et al.* and *Burdon, et al.* for at least the same reasons that claim 209 is allowable over this combination of references.

The Examiner has indicated that claims 213, 216, and 220 would be allowable if rewritten in independent form, including all the limitations of the base claim and any intervening

claims. Claims 213, 216, and 220 depend, either directly or indirectly, from independent claim 209, which is allowable over the applied references for reasons given above. Thus, claims 213, 216, and 220 are allowable as well, without further amendment.

The prior art made of record and not relied upon has been reviewed, but is not deemed pertinent to Applicants' invention. None of the references cited teaches or suggests a heat exchanger connected to a heat-generating device, including a microchannel disposed in a substrate, wherein the arrangement of the microchannel is selected to minimize the temperature differences across the heat-generating device.

In view of the above, it is submitted that the rejections of the Examiner have been properly addressed and the pending claims are in condition for allowance. Such action at an early date is earnestly solicited. It is also requested that the Examiner contact Applicants' attorney at the telephone number listed below should this response not be deemed to place this application in condition for allowance.

Respectfully submitted,

10/4/04
Date

John J. Timar
Registration No. 32,497
Attorney for Applicants

Womble Carlyle Sandridge & Rice, PLLC
P.O. Box 7037
Atlanta, GA 30357-0037
(404) 888-7412 (Telephone)
(404) 870-2405 (Facsimile)

PAGE 42/42 * RCVD AT 10/4/2004 3:26:00 PM [Eastern Daylight Time] * SVR:USPTO-EFXRF-1/0 * DNIS:8729306 * CSID:Womble Carlyle - ATL * DURATION (mm-ss):13-28